CARBIDE INSERT BIT DRILLING AT THE CLEVELAND-CLIFFS IRON CO. MINES ISHPEMING, MICH.

BY WALTER E. LEWIS

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by

Walter E. Lewis[1/]

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INTRODUCTION AND SUMMARY

This circular presents the method of making tests and apparent results of comparing performance of tungsten carbide insert bits and steel detachable bits by the Cleveland-Cliffs Iron Co. at the company's mines on the Marquette iron range of Michigan. The mines are at Ishpeming and Negaunee, Mich., and include the Cliffs Shaft, Mather "A", Cambria-Jackson, and Mather "B".

There are four general characteristic types of high-grade iron ore on the Marquette range. B. H. Boyum[2] classifies the Cliffs Shaft as "hard-ore" and the Cambria-Jackson and Mather "A" as "soft-ore" types of deposit. Shaft sinking through jasper, slate, and graywacke was in progress at this writing at the Mather "B", with completion at 3,100-foot depth in August 1949.

The many different kinds of rock and ore at the mines of the Cleveland-Cliffs Iron Co. and the experimental work being carried on with carbide insert bits make it possible to compare, generally, the carbide insert and steel detachable bit. The type of "hard ore" at the Cliffs Shaft mine required close study of the possible use of the insert bit, and their records are more complete than those of the "soft-ore" mines.

History and development of tungsten carbide tips inserted in rock drill bits have been covered by R. W. Adamson,[3] C. H. Vivian,[4] R. C. Sullivan,[5] and others.

Tungsten carbide insert rock bits have only recently been introduced to the domestic mining industry. Although unusual performance records are being reported at operations employing the insert bits, the general adaptability of the tool to all rock types and the advantages to be gained by using carbide insert bits remains to be demonstrated. Insert-bit performance is being observed at numerous mines and quarries throughout the United States.

The several mining operations at the Cleveland-Cliffs Iron Co. at Ishpeming, Mich., is one site where exhaustive comparative tests of insert and conventional steel detachable bits are currently in progress. Results to date are sufficiently impressive to be of general interest to the mining

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2/ Boyum, Burton H., Geological Exploration on the Marquette Range: Min. Cong. Jour., vol. 31, No. 8, Aug. 1945, pp. 29-32.

3/ Adamson, R. W., The Application of Hard Materials for Rock-Cutting Bits: Paper presented at the 1947 Annual Metal Mining Convention, El Paso, Tex., Oct. 27, 1947. Reprinted and distributed by Ingersoll-Rand Co.

4/ Vivian, C. H., Carset Bits for Rock Drills: Compressed Air Magazine, vol. 53, No. 11, Nov. 1948. Reprinted and distributed by Ingersoll-Rand Co.

5/ Sullivan, R. G., Tungsten Carbide Promises Faster, Cheaper-Drilling: E & M J. March, 1947.

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industry. The causes of bit failure and the adaptability of the bits to various types of rock are being investigated, and a summary of apparent results to date is presented in this report.

ACKNOWLEDGMENTS

The cooperative efforts of the following Cleveland-Cliffs Iron Co. officials are gratefully acknowledged:

C. J. Stakel. general manager.
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A. E. Lillstrom, development engineer, mechanical department.
S. W. Sundeen, mine superintendent, Cliffs shaft mine.
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J. S. Westwater, mine superintendent, Mather "B" shaft.
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Acknowledgment is also made to Ingersoll Rand Co. and Timken Roller Bearing Co. for furnishing current specifications for detachable carbide insert bits.

DESCRIPTION OF TUNGSTEN CARBIDE DRILL BITS

There are several domestic distributors of a cemented carbide insert detachable bit. All distributors have different specifications on their tungsten carbide insert bits with regard to the hardness of the inserts, reaming edges, clearance grooves, double-taper angles, single-taper angles, and wing construction. Each design is intended to aid materially not only cutting of the rock but also clearing the cuttings from the back of the hole.

Single-gage holes are recommended by some manufacturers, as gage wear is negligible in some formations. In other instances it has been found that the standard practice of reducing bit gage has improved over-all results.

Adamson 6/ classes the hardness of cemented tungsten carbide compositions as ranging from 85 to 93 Rockwell A, which corresponds to 67 to 82 Rockwell C and 9.0 to 9.2 on Moh's geological-hardness scale. The manufacturers report excellent results on tests in many kinds of rocks. Under certain conditions, faster drilling speed, little if any gage loss, reduction of air consumption, and savings in explosives consumption are a few of the many advantages that are reportedly gained from the use of the tungsten carbide cutting edge.

6/ See footnote 3.

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The types of attachments used on the rod for fastening the detachable carbide insert bit to the rod may be classified into three main types. These types of rod attachments are:

Type "A" - A threaded attachment machined on the rod without a rod shoulder whereby the button of the rod bottoms in the bit and the hammer blow is transmitted at this point.

Type "B" - A stud-type drill-rod attachment where a threaded stud is driven cold into the heated rod leaving a shoulder on the rod. The detachable bit is turned on the threaded stud, and the shoulder of the bit rests upon the shoulder of the rod; the hammer blow is transmitted at these points. The stud is made in sizes to fit various sizes of bits. The stud-type drill-rod attachment is shown in figure 1.

Type "C" - A threaded attachment machined on the rod, leaving a rod shoulder. The detachable bit is turned on the thread, and the shoulder of the bit rests upon the shoulder of the rod; the hammer blow is transmitted at these points. This type of threaded attachment is shown in figure 2.

There is one other attachment that may be classified as type "D". In it, the tungsten carbide tips are welded directly to steel detachable bits or conventional steel by conventional oxy-acetylene brazing methods.

The mines of the Cleveland-Cliffs Co. have experimented with all of these attachments.

CLIFFS SHAFT MINE

Because bit performance, among other things, is governed by rock types and mining methods, the condition under which comparative performance tests are made should be generally understood; therefore, the geology and mining method employed are briefly summarized.

General Geology[7/]

Ore occurrence is irregular at the Cliffs Shaft mine, ranging from 25 to 150 feet in thickness and from flat to 60° dip. The ore is a hard, dense, specular hematite and magnetite. In general, the high-grade iron ore is classified as "hard ore" and is found in the uppermost portion of the Negaunee iron formation immediately below the Goodrich formation, which is generally slate at the contact. The structure is a westward-plunging syncline. The ore follows the geological structure and not the bedding. Cross folding and both normal or multiple overthrust faults are known. Numerous dikes cut the structure, some of them occupying the fault zones. The ore horizon is underlain generally by a thick "greenstone sheet."

Locally there is an iron-bearing conglomerate series above the "hard ore." This series may lie directly on the hard ore, or it may be separated by a slate member. Locally, the conglomerate is sufficiently extensive and rich to be minable.

7/ See footnote 2.

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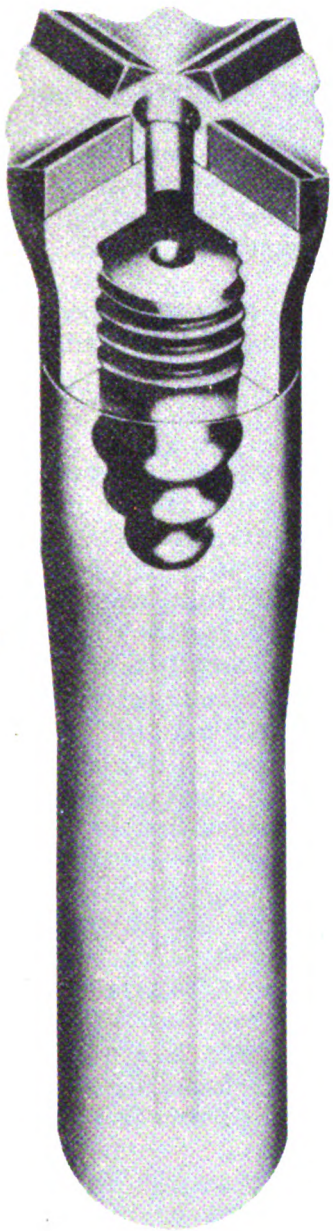

Figure 1. - Carbide insert bit with type "B" attachment.

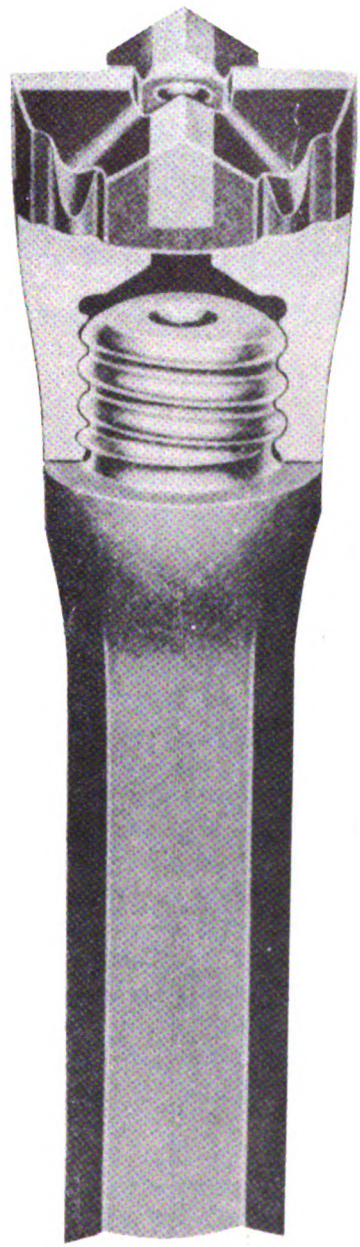

Figure 2. - Carbide insert bit with type "C" attachment.

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Mining Method

Room-and-pillar open stoping is used at the Cliffs Shaft mine. The ore is opened at 50-foot levels by breast stoping. Rooms 35 feet wide, separated by pillars, are driven from hanging to foot wall. As the group of parallel rooms along the vein is completed, the width of the ore body is apparent, and the pillars are then cut by crosscuts into sizes 25 by 25 feet; however, the pillar may be larger, depending on the condition of the back. Mining proceeds by underhand stoping with drifters mounted on tripods or jackhammers with jackleg air-feed mounting. Approximately 30 percent of the ore is left in the mine in the form of pillars and floor arches. Slate, dike rock, or one of the conglomerate members will slack on exposure to air; and where the hanging wall is one of these formations 8 to 15 feet of ore is left for support.

The miners work on a bimonthly contract system, receiving payment on the basis of the number of cars of ore broken.

Bit-Test Procedure

Compilation of records of carbide insert bit use at the Cliffs Shaft mine was begun in February 1948, when 22 1-1/2-inch, 4 point, carbide insert bits with type "B" attachment were placed in service. The bits required a 13/16-inch stud, and regular carbon drill steel was used. Until December 1948, records were kept on the new and resharpened bits used in each contract, and the average footage drilled per bit was computed in feet per bit use. Resharpened bits returned to a working place were not necessarily those that had been issued previously. S. W. Sundeen,[8/] recognizing that considerable differences in drilled footage were being reported from different contracts, decided to initiate a record that would enable close observation of the footage drilled in each contract with the type of drilling machine in use. The program, started December 1, 1948, includes a "Daily Record of Insert Bits Used" compiled in the form shown in table 1. The procedure involves returning to each contract their own resharpened bits. A monthly summary has been made from the daily records for each contract, which shows the bits worn, stripped, total footage drilled, and feet drilled per bit. These records have permitted the engineering staff to verify each contract carefully and to determine the performance of the bits in the exceptionally hard drilling rock and ore and the more average ground. Also, experimental work can be carried on in each contract with respect to the type of drilling machines and different types of tungsten carbide insert bits.

Keeping the record is not in itself difficult, as no more than 8 to 12 new bits were issued originally to each contract. The miners usually bring a string of 5 to 7 dull bits back to the shop at the end of each shift. The shopman sharpens the bits replaces new ones for discards, places them back on the bit string, and makes an entry after the contract number on the daily record of footage and bits used. If new bits are required, the entry is made under "bits issued." The daily record sheets are summarized monthly by the company's development engineer.

8/ Sundeen, S. W., mine superintendent, Cliffs Shaft mine, Ishpeming, Mich., personal communication.

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TABLE 1. - Sample of daily bit record sheet, Cliffs Shaft mine

DAILY RECORD OF INSERT BITS USED CLIFFS SHAFT MINE

Cont. No.	Bits issued		No. bits returned		Footage	Discarded bits	
	Same	New	In	Out		Worn	Stripped
March 30							
96	2	1	3	3	77	1	0
44	6	0	6	6	87	0	0
44	5	0	5	5	62	0	0
86	9	1	10	10	84	1	0
45	5	0	5	5	200	0	0
25	0	5	0	5			
91	3	0	3	3	110	0	0
23	6	0	6	6	66	0	0
44	3	1	4	4	50	0	1 broken stud
73	7	0	7	7	79	0	0
71	10	0	10	10	176	0	0
19	7	1	8	8	214	0	1
43	3	1	4	4	76	0	1
63	3	1	4	4	90	0	1
63	7	1	8	8	90	0	1
April 1							
26	9	0	11	9	72	2	0
25	4	1	5	5	240	0	1
80	1	1	1	1	75	0	1 broken stud
4	1	1	1	1	30	0	1 broken bit
104	0	5	0	5			
86	6	1	7	7	38	0	1 broken stud
73	8	1	9	9	54	0	1 broken stud
43	3	2	5	5	30	0	2

Cost comparison - Steel Bits and Tungsten Carbide Insert Bits

At present, the Cliffs Shaft mine is using both steel and carbide insert bits but complete change-over to the carbide insert type is contemplated. Time studies with the steel detachable bit revealed that, in exceptionally hard drilling ground it took as long as 2 hours to drill a 5-foot hole, and as many as 120 steel bits were needed to complete the hole. A total of 1,000 bits were needed to complete the round.2/ In the average drilling ground, 100 steel bits were needed for a drift round, starting with a 2-1/8-inch steel bit in order to bottom the hole at 1-5/8 inches. In contrast, the 4-point carbide insert bit with type "B" attachment drilled a hole of uniform diameter and in exceptionally hard ground has a drilling speed of 1 to 6 inches per minute, averaging 3 inches per minute. In average drilling ground, the drilling speed is 8 to 15 inches per minute.

The burden on each hole was the same with both types of bits. The smaller, single-gage blast hole reportedly required less dynamite than the tapered hole

2/ Madson, M. H., mining engineer, Cliffs Shaft mine, Ishpeming, Mich., personal communication.

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drilled by the steel detachable bits. Under such circumstances the drilling time per man hour, air consumption, dynamite required, and the possibility of longer feeds and lighter drills all enter into the actual cost per foot of hole drilled. To obtain exact costs will necessitate records extending over a period of at least a year after a complete change-over to carbide insert bits has been made.

The approximate cost of the steel detachable and the carbide insert bit per foot of hole drilled is shown in table 2.

TABLE 2. - Comparative cost per foot of hole drilled, steel and carbide insert bit, Cliffs Shaft mine (see Table 4)

Type of bit	Period	Total feet drilled	Bit uses 1/	Bits used	Feet per bit use	Feet per bit	Cost per bit use	Cost of bit per ft. of hole drilled
Steel....	Mar. 18-June 30, 1948	123,741	76,013		1.627		$0.143	$0.0878
Insert...	Dec. 1948	18,201		110		165		.0806
Insert...	Jan. 1949	19,052		170		112		.1132
Insert...	Feb. 1949	20,247		197		102		.1285
Insert...	Mar. 1949	25,057		190		132		.1006
Insert...	Apr. 1949	30,645		187		164		.0856
Insert...	May 1949	27,239		144		188		.0736
Insert...	June 1949	34,392		159		216		.0669

1/ A "bit use" is defined as a bit that has been placed in service either new or resharpened.

The table indicates that when a footage of over 160 feet per insert bit is obtained, the cost per foot of hole drilled is lower than the cost per foot of hole drilled with the steel bit. In the record period of December, the insert bit averaged 165 feet per bit, and the cost was lower than the steel bit cost in the period from March 18 to June 30, 1948. S. W. Sundeen 10/ considers the January, February, and March figures of $0.1132, $0.1285, and $0.1006, respectively, slightly high, because the cumulative need for culling to keep stud threads in good shape fell after the first of the year. The footage per bit gained in April, May, and June passed the 160-foot mark, and the cost of the insert bit per foot of hole drilled was less than the cost of the steel bit.

Results of Use of Tungsten Carbide Insert Bits

Table 3 summarizes the carbide insert-bit record from February 20, 1948, to December 1, 1948.

10/ See footnote 8.

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TABLE 3. - Tungsten carbide insert bit uses, Cliffs Shaft mine
(drilling speed 3 to 18 inches per minute)

Period	No. of contracts using carbide insert bits	Total feet drilled	Bit uses	Feet per bit	Feet per bit use
January	0	0	0		
February Feb. 20	5	2,879	51	130	
March					
April Apr. 14	4		72		15.5
May	10	4,856	263		18.4
June	19	11,743	426		27.5
July	22	11,236	648		17.3
August	22	10,703	551		19.4
September	30	14,535	604		24.0
October	26	18,111	590		30.7
November	27	12,781	465		27.5

During the period from May 1, 1948, to November 30, 1948, 83,965 feet were drilled with 3,547 bit uses, averaging 23.7 feet per bit use. In contrast to the average feet per bit use with the carbide insert bit, the steel bit, between March 18, 1948, and June 30, 1948, averaged 1.627 feet per bit use, which is shown in table 2 under the column headed "feet per bit use."

The new method of keeping records, started December 1, 1948, enabled the engineering staff to determine accurately the footage per bit with the type of drilling machine in use. Table 4 summarizes the records from December 1, 1948, to July 1, 1949.

TABLE 4. - Summary of tungsten carbide insert bit record, Cliffs Shaft mine
(drilling speed ranging from 3 to 18 inches per minute)
(see table 2.)

Month	Total feet drilled	Total worn discards	Total attachment device failures	Total bits used	Average feet per bit
December 1948	18,201	42	68	110	165
January 1949	19,052	65	105	170	112
February 1949	20,247	75	122	197	102
March 1949	25,057	61	129	190	132
April 1949	30,705	56	132	188	163
May 1949	27,239	67	77	144	188
June 1949	34,392	100	59	159	216

Experiments conducted in different working places during the period shown in table 4 convinced the staff of the Cliffs Shaft mine that the life of the insert bit was dependent on many different factors. Those factors that were most apparent were type of drilling ground, size of machine in use, upstroke or downstroke machine rotation, and the miner's technique. A high

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footage per bit was gained in December, but this was the result of the change-over in record keeping when new bits were issued to each working place. The footage per bit slowly leveled off in January, February, and March as discarded bits were returned to the shop.

Drilling machines in use in December 1948 and January 1949 were the following sizes:

2-1/2-inch bore jackhammer with jackleg air-feed mounting.
2-5/8-inch bore jackhammer with jackleg air-feed mounting.
3-inch bore drifters and stopers.
3-1/8-inch bore drifters and stopers.
3-1/2-inch bore drifters and stopers.

All of the above machines were upstroke rotation. Upstroke rotation machines have the rotation on the upstroke of the hammer, and the full power of the compressed air delivers the blow to the steel. With the upstroke rotation, failure was evident in the rod assembly and detachable carbide insert bit-attachment devices, varying to some degree in different working places, depending on the size and type of drilling machine in use. Commonly, in drifting and breast stoping when drilling back holes, the bit tended to run "tight and loose," which caused excessive thread wear and attachment-device failure.

In an effort to soften the hammer blow of the drilling machines and reduce the attachment-device failure, experiments in one working place were conducted in February with a downstroke rotation-equipped jackhammer with jackleg air-feed mounting. Downstroke rotation machines impart rotation on the downstroke of the hammer, and the power of the compressed air is divided between rotation of the steel and the hammer blow. The downstroke rotation gives a softer blow to the steel and tends to keep the bit tight on the rod, and the operator can crowd the feed of the machine and keep the bit close to the rock.

This test showed that the increased rotative power of the downstroke-equipped jackhammer with jackleg air-feed mounting assisted in smoother operation than an upstroke-equipped jackhammer. In addition, 97 feet per bit was averaged with the downstroke rotation machine, whereas, in contrast, only 57 feet per bit was averaged with the upstroke rotation machine in the same working place in January. An additional experiment was conducted in March with the downstroke rotation in exceptionally hard drilling ground (drilling speed 3 inches per minute). The 4-point carbide insert bits previously used with upstroke rotation jackhammers in this working place had averaged 30 feet per bit, with 3 worn discards and 14 stripped discards. In the test with downstroke-equipped jackhammers, an average of 63 feet per carbide insert bit was obtained with four worn discards and five stripped discards.

The increased footage that was gained from the carbide insert bits used with downstroke rotation jackhammers over those bits used with upstroke rotation jackhammers was noted almost immediately after the tests were begun, and as the results of increased bit life were evident with downstroke-equipped jackhammers, several jackhammers were changed over to downstroke rotation on

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March 18. The average footage drilled per insert bit in all working places prior to March 18 was 118, and after the change-over of several machines to downstroke rotation the average increased to 132 feet per bit.

Several downstroke rotation machines were in use in April, and the average increased to 163 feet per bit. Further changes in May and June from the use of the tripod-mounted 3-1/2-inch drifter (upstroke rotation) to a 2-5/8-inch jackhammer jackleg-mounted (downstroke rotation) resulted in a remarkable increase in footage drilled per bit and a substantial reduction in the cost of bit per foot of hole drilled (table 4).

The downstroke rotation with 2-1/2- and 2-5/8-inch bore jackhammers with jackleg air-feed mounting proved superior, as far as bit life is concerned, to the upstroke rotation in the type of ore and rock found in the Cliffs Shaft mine. Further experiments conducted by the engineering staff have shown that the 2-5/8-inch bore jackhammer is superior in this instance to large-bore machines, and the downstroke rotation with the smaller machines has materially increased the average footage per bit.

Drill manufacturers regard the upstroke rotation as standard, with downstroke rotation used only in special cases where drilling is in seamy and blocky ground. A. E. Lillstrom's[11] studies have shown that the smaller-bore jackhammers (2-1/2 to 2-5/8 inches) appear to be more suitable for drilling with the carbide insert bit in the ore and rock found at the Cliffs Shaft mine. In addition, downstroke rotation used on the smaller machines is a definite improvement over upstroke rotation, with respect to footage drilled per man shift and cost per carbide insert bit use. Prior to the use of carbide insert bits, the standard stoping machine was a 3-1/2-inch upstroke rotation drifter drill on tripod mounting using 2-1/8-inch starter steel. If further experimentation bears out what has been discovered from December 1948 through June 1949, the 2-5/8-inch bore jackhammer with downstroke rotation and pneumatic jackleg mounting will be used as the standard drill unit.

Further experimentation with the insert bit is pointed toward using a larger stud and bit to further lessen attachment-device failure.

Obviously, the same conditions under which the Cliffs Shaft engineering staff conducted these experiments may not apply to other mines and quarries throughout the United States, but certainly the Cliffs Shaft people have demonstrated that in their case changing to a lighter-type machine and softening the hammer blow has lengthened the life of the carbide insert bit. This was achieved largely by reducing the failure of the attachment devices and allowing the full life to be gained from the tungsten carbide inserts.

Sharpening Practice

From February 1948 to June 1, 1949, bits were sharpened on 8-inch by 3/8-inch silicon carbide wheels. These wheels were mounted on an 8-inch bench grinder, and the bits were hand-held and ground dry.

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11 Lillstrom, A. E., development engineer, Cleveland Cliffs Iron Co., Ishpeming, Mich., personal communication.

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Figure 3. - Bit skirt failure (type "B" attachment).

Type 1

The skirt of this bit failed during drilling with a downstroke 2-5/8-inch-bore machine. The ground was relatively soft, which caused rifling in the hole. Large pieces of cuttings apparently were broken off, which caused the bit to "square." The skirt of the bit probably failed because of the binding action of the rifled hole. The inserts are still in good condition.

Figure 4. - Broken stud (type "B" attachment).

Type 2

Approximately 1/2 inch of the 13/16-inch stud has been broken off and riveted in the bit. The failure occurred while drilling with a downstroke 2-5/8-inch machine. The threads near the shoulder of the bit have been stripped beyond repair by continuing to drill after failure. Reduced drilling speed and chattering of the drill rod should indicate this type of failure to the miner before thread strippage occurs. If the failure is detected before the stud is riveted within the bit, the broken stud portion can be removed and the bit reused. This bit has given good service, as noted by the worn seating of the inserts.

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Figure 5. - Thread strippage (type "B" attachment).

Type 3

Thread strippage that occurred while drilling with a downstroke 2-5/8-inch-bore machine was caused by rifling. Rifling of the hole and squaring of the bit placed excess pressure on the bit, and failure in the threads resulted. This type of failure can be compared to that of type 1. The actual cause of breakage, rifling of the hole and squaring of the bit, is the same, but in this case the weakest link in the attachment assembly is the bit threads. The inserts and insert seating are in good condition.

Figure 6. - Rod failure (type "B" attachment).

Type 4

This type of rod failure is common when using an upstroke machine. The rod has broken near the tapered end of the cold-driven stud attachment. Characteristic of drilling with upstroke machines in the Cliff shaft mine, the shoulder of the rod has been ground by the bit running tight and loose. The bit shoulder has ground into the rod shoulder approximately 1/8 inch. If failure had not occurred in the rod, thread strippage would have resulted eventually. In converting to a downstroke machine, the failure is transferred from the rod to the threads and bit skirt; however, longer life is assured to both rods and bits.

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Figure 7. - Insert failure (type "B" attachment).

Type 5

This type of failure occurred while drilling in exceptionally hard ground (drilling speed approximately 3 inches per minute). The machine in use was upstroke with 2-5/8-inch bore. Here, squaring of the bit as noted in type 1 is not in evidence. The bit has been resharpened many times and has given good service. Undue strain was not placed upon the attachment devices by rifling because of the nature of the ground.

Figure 8. - General insert failure (type "A" attachment).

Type 6

This 2-inch bit was used with a 3½-inch upstroke drifter. Approximately 60 feet was obtained before insert failure occurred. As is evident in the picture, the threads are approaching failure, and the bit life was limited regardless of the condition of the inserts.

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Figure 9. - Rod and stud failure (type "B" attachment).

Type 7

This type of failure is common when an upstroke machine is used. The failure is comparable to that of type 4, but breakage has occurred in the stud attachment rather than in the rod. As is common when drilling with upstroke machines in hard ground in the Cliffs shaft mine, the bit has been running tight and loose. The bit shoulder has ground into the rod shoulder approximately 1/16 inch. Failure such as type 4 and 7 will not, as a rule, damage the bit.

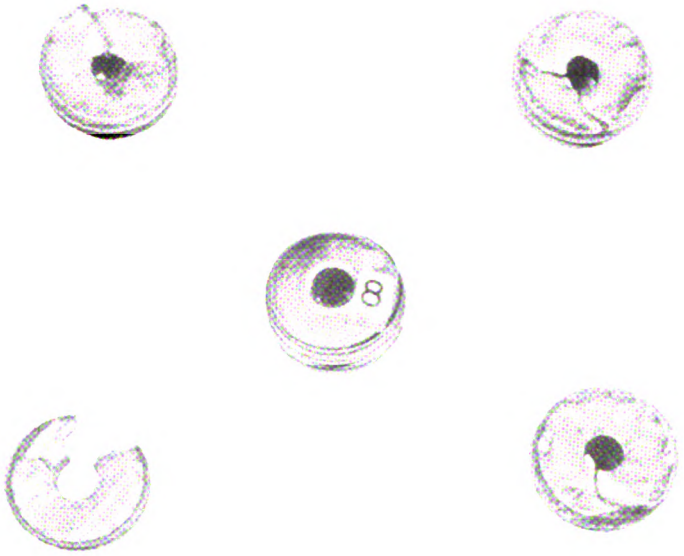

Figure 10. - Stud failure on threaded end (type "B" attachment).

Type 8

This is the principal type of failure in the Cliffs shaft mine after the change-over from upstroke to downstroke drilling machines. The breakage has moved from the back portion of the cold-driven stud, as is shown in figures 6 and 9, to the threaded end of the stud; however, longer life is gained before failure by using the downstroke machine. In many cases of this type of failure, the bit can be reclaimed by removing the broken portion of the stud.

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From June 1, 1949, a bit grinder has been in use. The bit grinder is mounted with a 12- by 1- by 1-1/4-inch silicon carbide wheel. The bits are held in a forming head. Water is used in this grinding, but only on the bit and not on the wheel. The wheels will dress from 130 to 150 drill bits. In the sharpening process bits are restored to proper cutting angles and taper. As a consequence, bit life seems to be increased.

Common Types of Carbide Insert Bit Failure

Improvement of the cutting edge of the carbide insert bit over that of the standard detachable rock bit has resulted in transferring failure and breakage to the attachment devices. In the experiments being conducted by the engineering staff at the Cliffs Shaft mine, it was found that failure is more likely to occur in any part of the attachment assembly other than the cutting edge. In many working places, actual worn inserts are in the minority, and the failure is transferred to portions of the rod, stud, and bit shoulder, skirt, or threads. Transferring failure of other parts of the attachment assembly indicates the necessity for investigation by the manufacturers of possible improvement of the attachment devices. Such improvement may come about through strengthening the parts of the bit, rod, and stud where failures are occurring.

Usually, when the inserts have become well worn, and their seating support has been thinned by constant resharpening, one of the inserts will either drop out of the seating or fracture to such an extent that only three cutting edges are in use. Complete destruction of the three remaining inserts is almost immediate after the failure of one insert. Breakage of one insert also will occur when the shoulder of the bit is not seated squarely upon the rod shoulder.

Upstroke-type drill machines may have been responsible for a serious type of insert-bit failure when back holes were drilled in drifting. In some contracts, where the ground is exceptionally hard (average drilling speed 3 inches per minute), the bit will run tight and loose on the threads and grind the shoulder of the bit into the shoulder of the rod. If the attachment devices of the rod do not fail under the grinding action, the bit threads will strip with resultant irreparable damage to the threads.

Experiments are being conducted on possible methods of salvaging the inserts in partly destroyed bits and replacing them in bits with worn inserts but otherwise in good condition; however, considerable experimentation will have to be done before it is determined if such a plan is economically feasible.

The more common types of failure in the Cliffs Shaft mine are shown on figures 3 to 10, inclusive. Failures have been classified into eight general types.

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MATHER "A" SHAFT MINE

General Geology

B. H. Boyum[12/] classifies the general type of ore in the Mather "A" as a "soft ore" deposit lying on the footwall Siamo slate within the Negaunee iron formation. The ore is a soft red, brown, and purple earthy hematite and goethite locally well compacted. The principal structure is that of a westward-pitching synclinorium open at the west end. The ore follows the geological structure and not the bedding. The footwall ore bodies are found in structural troughs formed by faults, folds, and dikes intersecting the slate.

Mining Method

Sublevel radial drill stoping and block caving is used at the Mather "A" shaft mine. The ore body is developed by a series of sublevels for stoping at vertical intervals of 25 to 50 feet. Mining begins on the highest sublevel retreating back in a direction parallel to the strike toward the central point raise. The bottoms of the sublevels are covered with plank to form a good floor over which to scrape. Caving is begun at the ends of the sublevels by blasting cuts (mills) above the timber set. Long-hole radial drilling is then started from the end of the sublevel. The broken ore entering the sublevel through the mills is dragged by power scrapers into the raise. Timber sets are not recovered.

Bit-Test Procedure

Insert bits with type "B" and type "C" attachments are used at the Mather "A" in main-level and sublevel rock-drift headings. Auger steel is used in ore development, and 2-1/4-inch steel bits are used in stoping. Economically, the steel bit is superior to the insert type in soft ore where the radial holes are required. In the "soft ore," drilling speed with the steel detachable bit averages 13 inches per minute, and it is not unusual to drill 50 to 100 feet per bit. The possibility of losing the hole, rod, and bit in the blocky ground is ever present; and under such circumstances the use on insert type bits increases the cost per foot of hole drilled. Further, the economy of changing over from the steel bit (cost, about $0.40) to an insert type (cost, about $15) is questionable where a drilling speed of 13 inches per minute can be obtained with the 2-1/4-inch steel bit.

Usually the procedure followed in all other working faces in the mine, especially those in barren rock, is to keep records of the performance of the insert bit until it is determined whether it is cheaper to use them than steel detachable bits. If it is found to be cheaper to use insert bits, the records are dropped, complete conversion is made to insert-type bits, and experimentation is started at some other working face.

Results of Use of Tungsten Carbide Insert Bits

H. Korpinen[13/] reports that records of comparison between the steel detachable bit and the insert bit with type "C" attachment, while drifting

12/ See footnote 7.
13/ Korpinen, Hugo, operations engineer, Mather "A" mine, Ishpeming, Mich., personal communication.

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in slate, disclose that the performance of the carbide bit is superior to that of the steel bit. Drilling time has been cut to approximately half that required with the steel bit. Drift footage per man hour has been increased, and the actual over-all cost of drifting has decreased.

Complete records on drifting with different types of bits were not available at this writing. General comparative data on the use of 3-inch and 3-1/2-inch upstroke rotation drilling machines are summarized in table 5.

TABLE 5. - General comparative data on the use of 1-1/2-inch insert bit with type "C" attachment and Mather "A" steel bit, 2-1/8 to 1-3/4 inches

Type of bit	Total length of drift, ft.	Total footage drilled	Average drilling speed, in./min.	(Chrome-plated threads) No. of bits used	Feet per bit	Cost of bit per foot drilled
Insert (type "C"..	400	13,600	20	12	1,133	$0.01
Steel bit.....			10			.06

Gage loss on the carbide insert bits used was slight after the above tests were completed. Insert wear was not excessive, but thread strippage failure was common. Further efforts to gain greater footage from the bits with stripped threads has been directed toward silver-soldering the bit directly to the rods. Present practice will be to continue soldering the bits to the rods until all inserts are destroyed.

CAMBRIA-JACKSON MINE

The Cambria-Jackson mine is classified by B. H. Boyum[14] as containing the "soft ore" deposits that lie on the footwall Siamo slate. The geology and mining method are similar to those of the Mather "A" mine.

Extensive drilling tests have not been made, but W. R. Aitkins[15] reports that tests with a 1-1/2-inch insert bit with type "B" attachment were made during the advancing of two 310-foot rock raises. The rock was a hard dense slate.

Raising was done with a stoper using straight-shank, 1-inch, quarter-octagon steel. Air pressure was 90 pounds and water pressure 50 to 60 pounds. Table 6 gives the information gained from these tests.

TABLE 6. - Drilling record of 1-1/2-inch insert bit with type "B" attachment in hard, dense slate, Cambria-Jackson

Total footage raise and drift	Feet drilled per round	Number of rounds	Total number of bits used	Footage drilled per bit	Cost of bit per foot drilled
713.....	45.6	148	29	232.7	$0.049

14/ See footnote 7.
15/ Atkins, W. R., mine superintendent, Cambria-Jackson mine, Ishpeming, Mich., personal communication.

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Upon completion of the test, six bits were still in usable condition. Gauge loss was slight. Loss of inserts and rod wear was not excessive. In some instances, the studs loosened after continuous rod use.

Further tests are being made to compare performance of other types of insert bits with that of the one with type "B" attachment.

MATHER "B" SHAFT

At this writing, sinking is in progress at the Mather "B" shaft on a daily 3-shift basis. Daily shift reports kept by the shaft foremen date back to October 21, 1947.

The shaft has penetrated generally five different series of beds. In succession, from the surface downward, these are: Jasper, slate, graywacke, slate, and slaty quartzite.

Equipment

Jackhammers are used for sinking. Upstroke rotation is generally used, but in places where seamy, blocky ground is encountered and fitchering is noted, the rotation is changed to downstroke. Steel bits were used from October 21, 1947, to November 22, 1947, and after November 22, 1947, the steel bits were replaced with 1-1/2-inch insert bits with the type "B" attachments.

Bit-Test Procedure

The insert bits are not run to destruction of the inserts. In the down-holes, such as are necessary in sinking operations, the bits lose gage to the extent that they can be resharpened only twice. The procedure followed is to place the resharpened bits on the longer steel changes and the new bits on the starters. The bits that have been taken out of use in the shaft are being saved for future mining operations. In sinking, the first 10 inches of the hole are drilled with 2-1/4-inch steel bits. This serves for placement of a "muck pipe," which keeps out rock fragments and allows the cuttings to clear from the hole. The average depth of a shaft round was 6.9 feet.

Results of Use of Tungsten Carbide Insert Bits

J. S. Westwater[16/] reports that after the changeover from steel detachable bits to insert bits, the number of holes per round remained the same, but powder consumption was reduced approximately one-half.

The footage per bit used in each rock type encountered as sinking progressed is shown in table 7.

16/ Westwater, J. S., mine superintendent, Mather "B" shaft, Ishpeming, Mich., personal communication.

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TABLE 7. - Drilling record of insert bits with type "B" attachment and steel bit in sinking at Mather "B" shaft

Type of formation	Total insert footage drilled	Average feet drilled per insert bit	Total steel bit footage drilled	Average feet drilled per steel bit
Jasper	86,468	87.3	13,837	6.3
Slate	31,162	85.4	3,280	9.1
Graywacke	25,551	49.7	2,855	6.1
Slate	11,625	85.5	1,460	3.7
Slaty quartzite	3,659	50.8	490	4.1
Average		76.3		6.2

Table 7 demonstrates the uniform drilling characteristics of the insert bit before it has been run to destruction. The average footage drilled per bit in slate in two different periods of shaft sinking is almost identical. This is in contrast to that obtained from the Cambria-Jackson mine, where an average of 232.7 feet per bit was obtained in raising through a hard, dense slate. The graywacke and slaty quartzite in the shaft are somewhat similar rocks, and the average footage per bit is also about the same in each rock.

Drilling time with the insert bit was half the drilling time with the steel bit. Prior to the employment of insert bits, an average of 10.5 feet was drilled in 1 man hour; with type "B" bits 21 feet was drilled in 1 man hour. Based upon the average cut per round of 6.9 feet, one man could drill three holes per hour with the insert bits whereas, otherwise, with steel bits, only 1-1/2 holes could be drilled per hour. Such a reduction in man hours of drilling time has resulted in a considerable saving in compressed-air consumption and the related economies to speedier sinking progress.

Common Types of Carbide Insert Bit Failure

Bit and insert failures are unusual at the Mather "B" shaft, as the bits are taken out of use when gage is lost to the extent of 1/16 inch. The more common types of failure of the attachment devices are similar to those found at the Cliffs Shaft mine.

The records kept by the blacksmith shop disclose that between October 2, 1948, and to May 1, 1949, there were 1,645 failures of attachment devices and rod assemblies. In this period the shaft penetrated four formations - jasper, slate, graywacke, and slaty quartzite. The percentage of failures of each type of device follows:

	Percent
Broken studs	42.2
Broken rods	31.4
Loose studs	10.3
Broken shank	16.0
Stripped threads	.1

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The stud usually breaks at about 1 inch back from the rod shoulder. This is the site of many similar failures at the Cliffs Shaft mine when attachment devices fail while using upstroke rotation machines. The type of failure is shown in figure 9.

Of the total failures, 10.3 percent were loose studs. This type of failure is unusual in the "hard ore" at the Cliffs Shaft mine, but it occurred in some instances in the Cambria-Jackson mine after continuous rod use during raising operations in a hard, dense slate. The absence of the type of failure at the Cliffs Shaft mine, and its occurrence in sinking at the Mather "B" shaft and raising at the Cambria-Jackson suggest that possibly it may be characteristic in only certain kinds of rock.

CONCLUSIONS

In the experimental work conducted at the various properties of the Cleveland-Cliffs Iron Co., changes in machines appreciably lengthened the life of the carbide insert bit. Briefly, light drilling machines with a downstroke rotation and a relatively soft hammer blow were required in "hard ore;" heavier machines with upstroke rotation have proved satisfactory in the country rock of the "soft-ore" deposits; and a 55-pound class, upstroke, rotation jackhammer is the most suitable for sinking through jasper, slate, graywacke, and slaty quartzite. The use of the carbide insert bit has contributed towards an increase in footage drilled per man hour, reduction in air consumption, and reported savings in dynamite at both the "hard-ore" and "soft-ore" mines and in shaft sinking at the Mather "B". The tungsten carbide insert bit costs are less than those of the steel bit per foot of hole drilled at the "soft-ore" mines; at the "hard-ore" Cliffs Shaft mine the cost is less when the insert bits average over 160 feet of drilling.

The tungsten carbide insert bit has a definite place in rock-drilling practice, but careful experimentation by each mining operator in his own type of rock will be necessary before time-tested methods of rock drilling can be discarded. In many mines, combinations of both types of bits - steel detachable and carbide insert - may prove to be most feasible to effect economy of operation. There is no standard rock by which the performance of different types of bits can be measured. Each general type of mine rock is an individual problem of bit performance.

Operators contemplating a change-over from the standard steel detachable bit to the carbide insert type or inserts hard-set on conventional steels will probably discover, in certain kinds of rock, a maximum drilling speed above which the change-over is not economical. A. E. Lillstrom[17] feels that the economical drilling speed with the steel detachable bit at the Cleveland Cliffs mines ranges between 20 to 24 inches per minute. In working places where the drilling speed is below this range, use of the carbide insert bit will give a lower cost per foot of advance or per ton of ore broken; and above the range the steel bit will give a lower cost per foot of advance or per ton of ore broken. There may be a different economical speed range for each type of rock or ore, but once the speed range is well-established, working places where carbide insert bits can be employed at less cost will become evident.

17/ See footnote 11.

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